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Measurement of scrubbing behaviour of simulated radionuclide in a submerged venturi scrubber

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A R T I C L E I N F O

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A B S T R A C T

Post Fukushima accident, the societal impact of radiological leakage to the environment necessitated further exploration and robust strategy to safeguard the nuclear reactor containment. In view of this, design of Filtered Containment Venting System (FCVS) plays an important role in depressurizing the reactor and preventing release of radionuclides to the environment. In this context, a venturi scrubber submerged in alkaline solution along with demister pad housed in a scrubber tank is investigated experimentally at prototypic conditions for retention of iodine vapors in the scrubber system. The hydrodynamics and the scrubbing performance of the submerged venturi scrubber is simulated at air flow rates of 1500–3500 lpm at the submergence height of 4 m. The iodine concentration retained in the scrubber tank and its bulk decontamination is measured by ICP-OES and ICP-MS analysis respectively.

It is observed that the overall pressure drop in the venturi scrubber increases with an increase in flow rate. The two phase axial pressure drop characteristics reveal an increase in the pressure drop in the converging section with increase in flow rate. The pressure drop also increases after the scrubbing liquid from the hydrostatic pool is suctioned and no recovery is found in the diverging section of the venturi scrubber. The iodine retention in the scrubber tank increases sharply with an air flow rates up to 2200 lpm after that the increase is gradual with the maximum of 95% retention at 3400 lpm. It is seen that in all the experiments the amount of iodine leaving the facility is negligible and the bulk decontamination is high. Further, effect of submergence height on the retention of iodine vapors in the scrubber tank is compared at 3 m and 4 m. It is seen that an increase in submergence height significantly increased the percentage of iodine arrested in the scrubber tank at 1700 lpm air flow but further increase in air flow rate has lesser impact on the iodine retention in the scrubber tank despite the increase in submergence height.

1. Introduction

The safety of nuclear reactors encompasses adequate removal of decay heat due to fission reactions occurring in the nuclear reactor; prevent over-pressurization of the containment that may occur due to the production of high enthalpy steam and limit the consequences of any unforseen event within the containment boundary. In the event of severe accident scenarios of nuclear reactors, the continuous steam production in the containment may lead to its over-pressurization which can eventually risk the integrity of the containment. This can further cause leakage of the radionuclides to the environment if depressurization is not ensured by passive safety systems in the nuclear reactor. Amongst many of the radioactive fission products released during an accident, the radionuclides that could potentially pollute environment and harm public on its exposure are Cesium-137 and Iodine-131 (World Health Organization, 2011). Cesium compounds are mostly released in aerosol form while iodine is released in both aerosol and vapour form from the nuclear core. Iodine vapour is easily ingested in the human body and is highly hazardous. Cesium compounds have high solubility in aqueous solutions while iodine needs chemical additives to be added and is soluble only in alkaline solutions.

To carry out these functions of depressurization and capture of harmful radionuclides, installation of Filtered Containment Venting System (FCVS) is recommended in nuclear reactors (Rust et al., 1995; Jacquemain et al., 2014). The FCVS design consists of multiple venturi scrubbers submerged in a pool of aqueous solution with metal fibre filters. Typical geometry of a Pease-Anthony type venturi scrubber, which entrains liquid in the form of jets, consists of three sections; a converging section which accelerates the air flow; a uniform diameter section known as throat section having nozzles which draws in liquid

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Nomenclature

Q_t	inlet flow of air to the venturi scrubber (lpm)
Q_{so}	flow rate for measuring iodine concentration at the outlet of the venturi scrubber (lpm)
W_d	total weight of iodine dissolved in the sampling bottles (μg)
W_c	weight of iodine charged in the iodine dispenser (g)
DF	decontamination factor
F_i	concentration of iodine reported in the sampling bottles per unit volume from ICP-MS analysis (ppb)
DPT	differential pressure transmitter
PT	pressure transmitter

from the submerged pool during operation and the diverging section which allows for recovery of pressure and deceleration of flow.

There are two important aspects related to the performance of venturi scrubber, i.e. the hydrodynamics and removal of radionuclides which are interconnected. Lehner (1998) and Ali et al. (2013) measured the liquid flow rate entrained in the scrubber in self-priming and submerged conditions of operation respectively. In both the studies, the relative increase in the liquid flow rate with the decrease in throat gas velocity at a fixed operating height was concluded. Horiguchi, et al. (2013) observed the entrainment behaviour in a self-priming venturi scrubber and found that at high gas velocity there was no suction of liquid in the venturi scrubber. It was also observed that with increasing gas velocity, the liquid flow suctioned through the nozzles at the throat first increased and then decreased to almost zero. Nakao et al. (2016) found that the ratio of the liquid film and droplets were about 80–95%

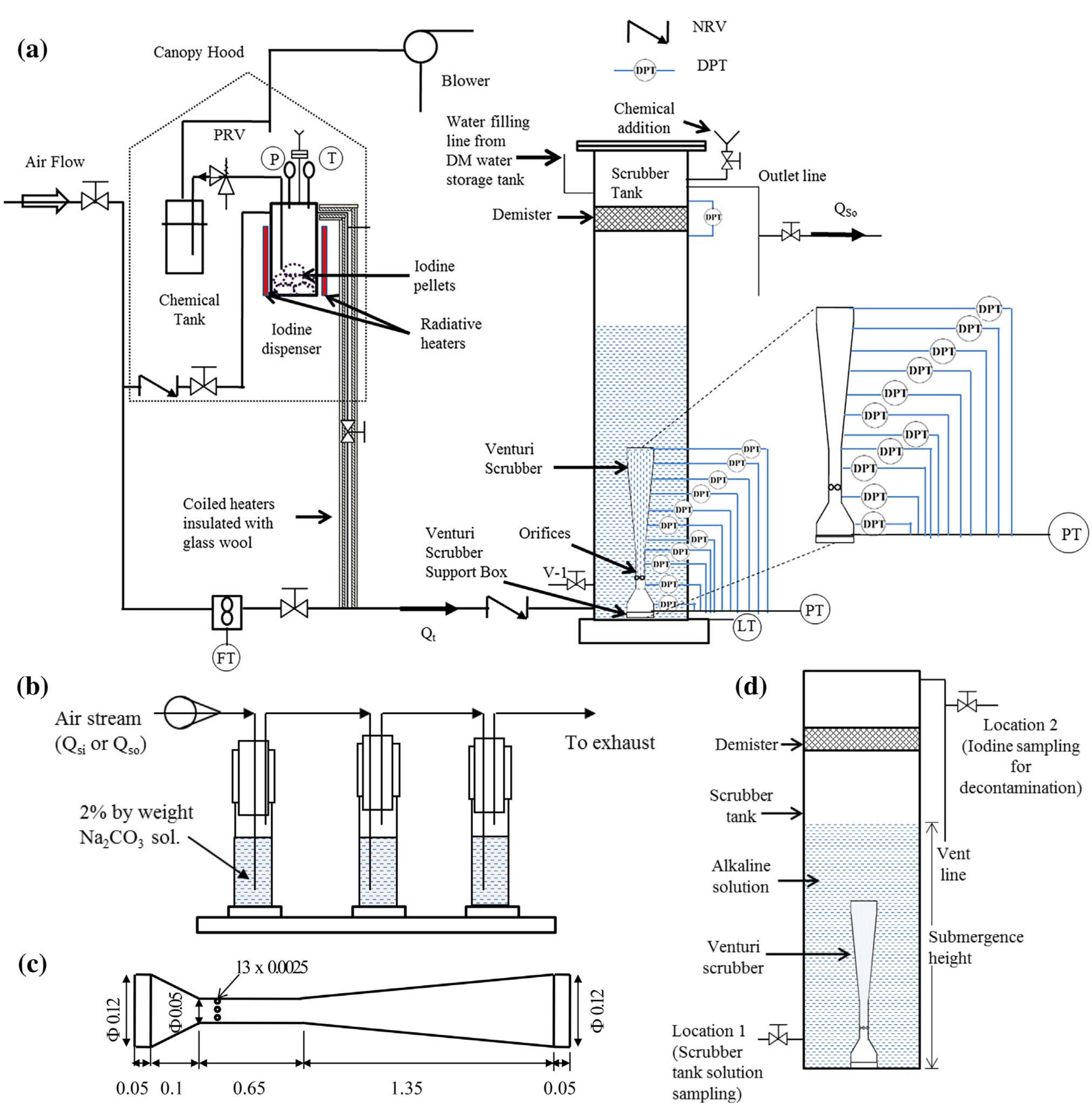

Fig. 1. (a) Schematic of experimental set up. V-1 (Location-1) : Scrubber tank sampling; QSo (Location 2): Flow rate for Measuring Iodine Concentration at the outlet of the venturi scrubber; Qt : Inlet Flow of air to the venturi scrubber (b) Sampling arrangement for measuring iodine vapour decontamination factor. (c) Venturi scrubber dimensions (in m). (d): Location of sampling ports in the experimental set up.